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Beyond the Usual Approach of Chemistry Teaching in High Schools*

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There is a huge challenge of high failure rate in physical science across the world and South Africa, in particular at the high school level in recent times. This is in spite of the fact that both the educators and learners go to schools almost on daily basis perhaps doing the same thing in the same way and manner and achieving the same level or less quality results annually. The main objective of this research was to investigate beyond the usual approaches of teaching chemistry by the educators in order to determine ways and practices that can positively influence the educators' teaching efforts and foster increased pass rate and quality of passes in Physical Sciences. Twenty-seven and 33 learners in their non-randomized intact classes were involved in the control and intervention classes respectively in two different high schools believed to have always underperformed at matriculation examinations in a suburb of Pretoria. The research made use of active learning model and a special form of cooperative learning strategy nick-named "goat and sheep method" with extra activities including animation to teach the experimental class and compared learners' performances with those of the control group that were taught the usual way. It was found out that upward of 87% of learners in the intervention class showed remarkably improved pass rate in quantity and quality in the post-test. Also, the topics taught became more learner-friendly and the educator achieved higher confidence and proficiency in dealing with the subject. Proper application of the teaching method described in this study enhances chemistry educators' and learners' performances anywhere.

Keywords: goat and sheep method, cooperative learning, active learning, animation, redox reactions, electrochemistry

Introduction

There has been a steady decrease since recent years in the pass rate and quality of passes recorded for Physical Sciences (particularly in chemistry) at the FET (Further Education and Training) band as have been evidenced by the matriculation results. Masombuka (2010) noted that about 580,577 matriculants sat for the 2009 examination and almost 230,000 of them failed. It was further observed that a greater preponderance of the failures was those that did mathematics and Physical Sciences. The downward trend became noticeable since 2003 and according to the Minister of Basic Education (2010), 132,988 students achieved above 40% mark for Physical Science in 2009, compared with 144,830 in 2008. The minister, Angie Motshekga blamed

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poor teaching among other factors as the causes of the appalling students' achievement levels at matriculation examinations. No doubt, some things were being done by the educators all these years and yet, the results have not improved, and rather a steady decline has become the case. Achieving the great need to improve the situation is expected to start at the high school level where a solid foundation should be laid in preparation for university and professional trainings.

The main objective of this research was to investigate beyond the usual approaches of teaching chemistry by the educators. This is in order to determine ways and practices that can positively influence the educators' teaching efforts and foster increased pass rate and quality of passes in physical sciences in the country. The problem of this study is hinged on the fact that the number of candidates that would like to take up science, medical and engineering courses at the university levels is fast depleting. This is a serious threat to the continuous scientific and industrial growth aspirations of a nation. It is expected that a science educator thinks science teaching as a purposeful means to an important end, student's learning (Staver, 2007). The problem of this study, therefore, is to identify some approaches and practices that are beyond the usual and which can help the chemistry educator to increase his/her efficiency and achievement of the students.

To ensure that students increase their performances levels and pass rate connotes, the application of teaching strategies can actually promote active learning.

A Model of Active Learning

A model of active learning is shown in Figure 1.

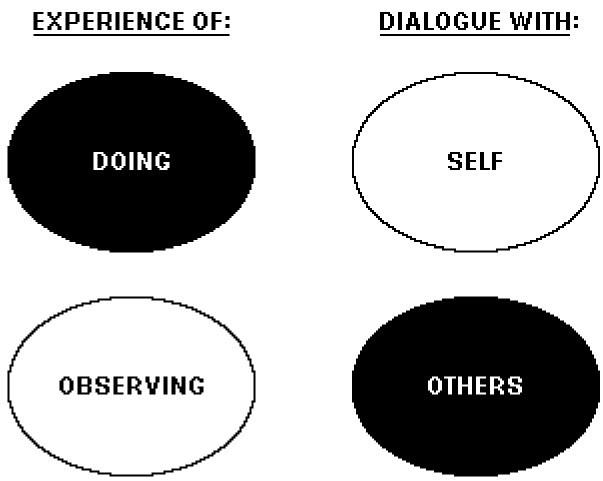

Figure 1. Dee Fink model of active learning.

Explanation of the Components

Usually, the most traditional teaching consists of little more than having students read a text and listen to a lecture, a very limited and limiting form of dialogue with others. Dee Fink (1999) recommended some steps for implementing the active learning model shown in Figure 1, which include:

(1) Expansion of the kinds of learning experiences the educator creates by creating small groups of students and ensuring that they make a decision or answer a given question at a given time, determining ways to engage students in meaningful dialogs about the topic or subject being considered, helping students to directly or vicariously observe what they are learning and making sure that students actually do what they need to learn;

(2) Applying the "power of interaction" by ensuring the use of more of the four components of the model of active learning in the process of teaching to add variety and enhance students' interest. A proper connection of the components in an interactive manner brings about an increased educational impact both to the teacher and students, thereby granting them the advantage of "power of interaction" (Dee Fink, 1999). For instance, a teacher might use a mixed approach in his/her class by discussing a topic with the learners, assigning the learners to some groups of few membership, giving them individual and group tasks and setting them into action among themselves with him/her moderating the whole exercise. By so doing, the learners and the teacher share from active interaction which eventually promotes active learning;

(3) Providing dialectic between experience and dialogue by creatively setting up dialectic of learning activities in which students share new experiences and engage in a deep and meaningful dialogue. This provides the opportunity for the students to experience significant and meaningful learning that helps them to improve their overall performances especially in chemistry.

It is becoming an open knowledge that the level and type of motivation shown to the learners significantly affects their quality and height of performance in whatever programme they are involved. Barbara (1999) observed that educators can encourage learners to become self-motivated independent learners by helping learners to find personal meaning and value in the materials provided, assigning tasks that are not too easy nor too difficult, making the learners feel that they are valued members of a learning community and creating open and positive atmosphere that can foster learners participatory and effective learning. Such will amount to good everyday teaching practices which eventually enable the learners overcome learner apathy. It further implies that enthusiastic educator with a genuine interest of students and what they learn to enhance students' motivation, invariably promotes learners' performances in the subject. The saying that "expectations affect performance" is not a mockery. When learners believe that they can learn something, they show readiness for it irrespective of its level of complexity. A chemistry educator is expected to observe the importance of variety in the reawakening of learners' involvements in the learning task and their motivations to learn instead of the usual routine talk and chalk method that brings boredom and disgusting feelings in the learners and hence less effective learning taking place. This can be done by incorporating a variety of teaching activities and methods in the subject, such as role playing, discussion and demonstrations, thereby bringing the understanding of the subject matter closer to the learners.

Effective teaching of chemistry like other sciences demands consistency with the nature of scientific inquiry. Project 2061 (2010) observed that sound teaching usually starts with questions and phenomena that are interesting and familiar to learners as they try to find answers to such questions. The approach involves active engagement of learners and use of team approach to ensure frequent group activities in the classroom. It is usual to see scientists and engineers work mostly in groups instead isolated investigators. Learners in their groups come to common understandings and can always inform each other about procedures and meanings of the task at hand. By so doing, there is team responsibility, feedback and communication which become more realistic than the experiences of the usual individualistic textbook-homework-recitation approach. A purposeful and effective teaching of chemistry and science in general should reflect scientific values which culminate in curiosity, creativity, spirit of healthy questioning, promotion of aesthetic values and avoidance of dogmatism among the learners (AAAS (American Association for the Advancement of Science), 1989).

This study made use of a metaphorically-named method of teaching called "goat and sheep instructional method" (Ochonogor & Ajaja, 2005). It is a special form of cooperative instructional teaching style developed and researched from 2001 to 2004 by this author. As a universal truth, goat and sheep are domestic animals usually kept for similar economic gains, such as meat, cheese, hides and skin products. Characteristically, a goat is known to be a smart and active animal and shows a high rate of comprehension under a short time of conditioning likened to teaching. Goat easily responds to commands and nick-name given to him/her by the owner(s). The animal, sometimes, shows some elements of stubbornness which is comparable to the attitude shown by some more active and intelligent learners at one time or the other excepting a few. On the other hand, the sheep is a good follower of anyone that stands as a leader of the flock and will like to be in groups in most cases. Sheep is less active and perhaps learns slower than the goat. In other words, a sheep is a ready animal to learn from the peers' irrespective of the condition. A mixed flock of goat and sheep is a mixed multitude of high, middle and low reasoning animals just as it is the case of any class of learners composed of high, middle and low achievers in the school system. The essence of carefully working with "goats" and "sheep" in a common flock is to produce a set of friendly animals that would have gained high level knowledge and intelligence from among them for higher performance at any given time or situation. Under the guidance of the owner (teacher in a classroom situation), the "goats" and "sheep" cooperate with one another, contribute to a common task and consequently share the joy of achievement in terms of cognitive and social development.

The choice of "goat and sheep" method in this study is in support of Staver (2007, p. 8) that effective science teachers believe and act in these ways:

(1) Respect and accept the unique perceptions of individual learners;

(2) Reflect on and consider learners' prior knowledge and interests when selecting and using specific strategies and techniques;

(3) Believe that all students can and will learn;

(4) Create a challenging, but non-threatening learning environment;

(5) Commit to the learning and intellectual growth of all learners;

(6) View oneself as capable, dependable and generally positive;

(7) Believe that one can teach effectively and that effective teaching will lead to positive learning outcomes.

Procedure for the Use of "Goat and Sheep" Method

The procedures for the use of "goat and sheep" method are as follows:

(1) The educator is expected to consciously identify the likened "goats and sheep" in the class according to the description given above without actually calling the learners such derogatory names of "goat and sheep". This should be done by applying his/her experience and knowledge of the learners;

(2) The educator clearly states the instructional objectives (D. Johnson & R. Johnson, 1984a, 1984b; Shlomo, 1980, 1994). This enables the educator to design suitable level of knowledge and task expected to pass to the learners. This step further helps the educator appropriate evaluation tool to determine the level of learners' comprehensions, performances and achievements and hence correctly identify the "goats and sheep" after teaching the topic to the general class;

(3) The educator attaches the identified "sheep" to each "goat" to form small learning groups. The size of the groups depends on the number of "goats" available while each "goat" is made to act as the leader of the group and "sheep" as the follower(s);

(4) The task for each group is well defined and handed over to the group leader with clear instructions

including: (a) ensure that every member of your group follows and participate in your group task; (b) leave no one in the dark in the process and explain every step taken to the group members as friends. The direction and level of communication expected here is horizontal because they all learners working, explaining, discussing and observing among themselves. Ochonogor and Ajaja (2005) observed the general view that the rate of comprehension of subject contents is higher when students teach themselves after the teacher's normal programme with them. They learn more and faster as friends and colleagues than the "down-the-line" or "up-the-line" communication direction of the educator to learner and learner to educator respectively; and (c) always say to the members that they all have the opportunity to lead as they work towards achieving the group goal set by the educator;

(5) The educator should avoid grouping all "goats" or all "sheep" together. They should be well mixed up and without prejudice. Heterogeneous group membership should be pursued as much as possible irrespective of race, ethnicity, religion or economic level;

(6) Opportunities to motivate the learners should always be sort and maintained by the educator, especially as it affects chemistry and the other sciences. This could be by ensuring that the expected practical activities in the topic being treated is well taught and demonstrated to the learners particularly the group leaders for onward transmission to others and practice among them. The educator should not hesitate to use improvised materials in the absence of real materials aiming at making the lesson a captivating one. Such improvisation could be in the form of locally available materials, computer simulations and animation;

(7) The educator should integrate guided inquiry approach (Kuhlthau, Mantniotes, & Caspari, 2007) into the process and must not leave the learners to themselves. He/she should join the learners in planning and executing the learning process with an adequate motivation with activities to enable them perform and achieve more and higher than usual;

(8) Consider the approach as capable of promoting deep scientific understanding through teaching that mirrors the nature and characteristics of inquiry in science, the values of science and the body of scientific knowledge (Staver, 2007).

Methodology

A mixed method of qualitative and quantitative approaches was adopted in this study with a quasi experimental pre- and post- test non-equivalent control design. Qualitatively, the study conducted a survey across the education districts in Gauteng using interview schedule and questionnaires on identified less-performing high schools chemistry educators and learners. The interview schedule and questionnaire were used to determine some chemistry topics that learners find difficult to comprehend, the present approach used by their teachers and why they find such topics difficult. The initial survey carried out on 30 randomly sampled learners showed 80% (24 of the learners) state that they find redox reactions and electrochemistry in general among others as difficult to comprehend and that physical science (chemistry) teachers teach them by simple lecture method, individual portfolio assignments, with very little or no practical activities. The contents of the questionnaire and interview schedule were based on three research questions.

Research Questions

The three research questions are as follows:

(1) What is your most difficult topic to learn in chemistry aspect of physical science?

(2) Why do you experience difficulty in comprehending the topic(s) stated above?

(3) How much of practical work do you undergo with your chemistry educator?

Hypotheses

Two hypotheses were stated for test at $p < 0.05$ as follows:

(1) The group taught chemistry with the study teaching approach does not significantly differ in performance from those taught the same topics in the usual conventional way;

(2) Learners do not show significant differential levels of motivation in chemistry whether taught with the study teaching approach or the usual conventional way.

The quantitative approach of this study culminated in an intervention programme involving the teaching of redox reactions and electrochemistry in both the experimental and control classes in two different high schools for four weeks. The samples for the intervention classes were naturally composed of intact class membership. The control group had 28 learners while 32 learners were in the experimental group. Each of the two topics was taught for two weeks with special lesson note and work schedule prepared by the author. A pre-test was administered on all the subjects before the commencement of the teaching programme using two educators having similar degree qualifications but differently trained for the purpose of this research by the author. The "goat and sheep" approach was well taught to one of the educators for special application with varieties of activities, while the other was made to teach the same topic but in the usual way to his learners.

The educators used in this study were made to teach redox reactions as a part of chemical equilibrium in the first two weeks and then electrochemical cells and electrolysis as a part of electrochemistry in the last two weeks of the study. This was because a sound knowledge of redox reactions forms a solid foundation for proper understanding of electrochemistry ensuring that proper partial equations and steps for redox reaction calculations introduced in the first two weeks were well applied in the last two weeks. Furthermore, the educator in the experimental school ensured the use of the "goat and sheep" method described in this study and provided necessary supports to the learners. Both educators used in the study taught the same contents to their groups of learners and administered the same pre- and post- tests to them accordingly. The author marked the scripts and analyzed the scores to test the two hypotheses of the study.

Table 1 shows elements in their metallic characters from Li (lithium) through to Au (gold) and the level of reactions with water, steam and dilute acids. Na (sodium), Mg (Magnesium), Aluminium, Zn (Zinc) and Cu (Copper) metals were variously provided and used accordingly in the teaching programme providing extra activities especially in the experimental school.

Example of Redox Reactions

The individual components of these reactions can be discussed as follows (see Figure 2). If a chemical substance causes another substance to be oxidized, it is called the oxidizing agent. In the equation above, Ag^+ is the oxidizing agent, because it has caused Cu(s) to lose electrons. An oxidant is reduced in the process by a reducing agent. Cu(s) is, naturally, the reducing agent in this case, as it caused Ag^+ to gain electron

Figure 3 shows a simple example of steps to calculate electrode potentials and stoichiometric applications in redox and electrochemical reactions. It is a template that any chemistry educator can use to simplify such calculations to the understanding of the learners. The research educator in the experimental school made use of this template as one of the unusual approaches to enhance learners' performances in the subject.

The research teaching programme covered electrochemical reactions are as follows (see Table 2).

Table 1

Electrochemical Series Showing Reactions With Water, Steam or Acids

water, steam, or acids	Li	$2\ Li(s) + 2\ H_2O(\ell) \rightarrow 2\ LiOH(aq) + H_2(g)$	The most active (most strongly reducing) metals appear on top, and least active metals appear on the bottom. A more active metal (such as Zn) will donate electrons to the cation of a less active metal (Cu^{2+}, for example). Notice the special role of hydrogen here; although H_2 does not have the physical properties of a metal, it is capable of being "displaced" (a rather archaic term seldom used in modern chemistry) from H_2O or H^+-containing (acidic) solutions. Note that the "active" metals are all "attacked by acids", what this really means is that they are capable of donating electrons to H^+.
	K	$2\ K(s) + 2\ H_2O(\ell) \rightarrow 2\ KOH(aq) + H_2(g)$	
	Ca	$Ca(s) + 2\ H_2O(\ell) \rightarrow Ca(OH)_2(s) + H_2(g)$	
	Na	$2\ Na(s) + 2\ H_2O(\ell) \rightarrow 2\ NaOH(aq) + H_2(g)$	
displace H_2 from steam or acids	Mg	$Mg(s) + 2\ H_2O(g) \rightarrow Mg(OH)_2(s) + H_2(g)$	
	Al	$2\ Al(s) + 6\ H_2O(g) \rightarrow 2\ Al(OH)_3(s) + 3\ H_2(g)$	
	Mn	$Mn(s) + 2\ H_2O(g) \rightarrow Mn(OH)_2(s) + H_2(g)$	
	Zn	$Zn(s) + 2\ H_2O(g) \rightarrow Zn(OH)_2(s) + H_2(g)$	
	Fe	$Fe(s) + 2\ H_2O(g) \rightarrow Fe(OH)_2(s) + H_2(g)$	
displace H_2 from acids only	Ni	$Ni(s) + 2\ H^+(aq) \rightarrow Ni^{2+}(aq) + H_2(g)$	
	Sn	$Sn(s) + 2\ H^+(aq) \rightarrow Sn^{2+}(aq) + H_2(g)$	
	Pb	$Pb(s) + 2\ H^+(aq) \rightarrow Pb^{2+}(aq) + H_2(g)$	
	H_2		
Cannot displace H_2	Cu		
	Ag		
	Pt		
	Au		

Note. Retrieved from http://atoine.frostburg.edu/chem/sense/101/just-ask-antoine.shtml

$$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$$
$$2Ag^+(aq) + 2e^- \longrightarrow 2Ag(s)$$

$$Cu(s) + 2Ag^+(aq) + 2e^- \longrightarrow Cu^{2+}(aq) + 2Ag(s) + 2e^-$$
or
$$Cu(s) + 2Ag^+(aq) \longrightarrow Cu^{2+}(aq) + 2Ag(s)$$

Figure 2. Redox reaction between solid Copper metal and Silver solution.

Data Analysis, Findings and Discussions

By the way of providing answers to the research questions of this study, the learners' responses to the interview schedule and questionnaire were analyzed. Question 1 sorts to find out which of the chemistry topics the learners find most difficult to comprehend and 25 (83.3%) out of 30 stated redox reactions and another 23 (76.7%) out of 30 quoted electrochemistry as most difficult among others. According to them, these topics are too abstract as they involve movement of electrons which are not visible. They further added that the involvement of calculations in the topics makes them more difficult. They find it hard to believe the calculations of invisible entities. Question 2 sorts to determine the reasons why the learners find their stated topic(s) most difficult and 21 (70.0%) of the 30 respondents expressed some serious shortcomings about the approach by which they are usually taught by the educators which has always made more of passive listeners in the class. Some 24 (80.0%) of the respondents further noted that they are not always well motivated to study and learn chemistry with full interest. This could be one reason for the obvious and usual poor performance of physical science learners in many countries including South Africa. A learner is more disposed to learn what he/she is interested to learn and interest is greatly influence by level and type of motivation provided to the learner. Twenty-four (80.0%) of the 30 respondents stated that very little or no practical works are done with them in the process of their learning chemistry aspect of physical science. They explained that most of the required facilities and equipment for chemistry learning are foreign in name and physical representations to them. This situation further made chemistry more abstract to the learners than usual. It was based on this obvious universal reason that this study made use of available and improvised materials with additional student-lead activities in the experimental school and compare the outcomes with those from the control school where things were just done in the usual way.

Redox Reactions Calculator

Top of Form
Calculate the electrode potential for a half-reaction, with inputs being the concentrations and stoichiometric coefficients of the reactants and products and the number of electrons transferred:
Input Values:

Standard Reduction Potentials (volts) =	Fe(2+)+ 2 e(-) --> Fe (s)

Concentration of Reactant A (molar) =	0.0100 dm^3	Stoichiometric Coefficient of Reactant A =	1
Concentration of Reactant B (molar) =	0 dm^3	Stoichiometric Coefficient of Reactant B =	0
Concentration of Product C (molar) =	1 dm^3	Stoichiometric Coefficient of Product C =	1
Concentration of Product D (molar) =	0 dm^3	Stoichiometric Coefficient of Product D =	0
Number of electrons transferred (n) =	2		

Results:

Standard Potential E_0 (from table) =	volts	E (calculated) =	volts

Bottom of Form
Top of Form
Input Values:

Potential of first half-reaction (be careful with sign!) =		Potential of second half-reaction (be careful with sign!) =	

Results:

E (calculated) =	volts

Developed by
Shodor (1996-2008)

Figure 3. Redox Reactions Calculator (in cooperation with the Department of Chemistry, the University of North Carolina at Chapel Hill)bottom of form.

Table 2

Electrochemical Reactions Taught in the Research Classes

Electrical work From spontaneous Oxidation-reduction reactions	Voltaic cells	Standard-state Cell potentials for Voltaic cells
Predicting Spontaneous Redox reactions From the sign of E	Standard-state Reduction half-cell Potentials	Predicting Standard-state Cell potentials

A *t*-test statistics was used to test the two hypotheses of this study stated as follows:

(1) The group taught chemistry with the study teaching approach does not significantly differ in performance from those taught the same topics in the usual conventional way;

(2) Learners do not show significant differential levels of motivation in chemistry whether taught with the study teaching approach or the usual conventional way.

Table 3

T-test Result for the Post-test Scores of the Control and Experimental Groups

Variables	*N*	Mean	*SD*	Std error	*df*	*t*-cal.	*t*-critical
Control group	28	54.57	10.94	5.5587	58	1.7033	3.360
Experimental group	32	74.66	12.66				

As shown in Table 3, the means score of the learners in the control group form the post-test is 54.57 and the experimental group learners have a mean score of 74.66. Though both groups performed poorly in the pre-test administered on them with mean scores of 41.21 and 41.31 respectively, they showed some gain scores in the post-test. The learners post-test results showed 13 (46.4%) of the 28 in the control group that scored between 60% and 70% while 28 (87.5%) of the 32 in the experimental group scored from 60% to 100%. The percentage gain score is 5.19 and 46.19 respectively. This implies that the teaching approach and the associated predetermined extra activities adopted in the experimental school formed the major source of the high gain scores and hence higher performance of the learners in the experimental group. Table 3 further shows that calculated *t*-value is 1.7033 and is less than the critical *t*-value of 3.360 at a degree of freedom (*df*) of 58 resulting in the rejection of the hypotheses stated above. In other words, the group taught chemistry with the study teaching approach differed significantly in performance from those taught the same topics in the usual way. The learners also showed significantly higher motivation level culminated in their levels of interests and positive attitudes and perceptions towards chemistry than those in the control group.

Implications and Conclusions

The study found out that an upward of 87% of learners in the intervention class showed remarkably improved pass rate in the post-test. The topics taught became more learner-friendly to the learners/students. Furthermore, the learners saw the research-teaching approach very rewarding in terms of social interactions among themselves and with their teacher in the experimental class. In the same vein, the educator achieved higher confidence and proficiency in dealing with the subject with little efforts. The implications of all these are that the approach enhances learners' participation in the process of teaching and learning, thereby increasing their abilities to achieve more than through the conventional approach. The learners did not only hear the teacher's/educator's talk, but took instructions from both the teacher and their fellow learners in their small groups. The process helped to remove the usual fear and intimidation learners use to have in an environment where the teacher is the almighty. The approach increases the level of understanding and cognitive achievement through the horizontal level of communication among the learners. In addition to increased level of academic achievement, the learners enjoy leadership training by the use of this study's teaching approach which will eventually help them as future leaders. The approach also enables the teacher/educator to see the need for proper understanding of the learners' psychology and ensure the development of skills that will positively influence a greater proportion of learners the chemistry/science class.

It is concluded that the "goat and sheep" method as a form of cooperative learning style coupled with appropriate activities including animation as used in this study proved very effective. It is a less expensive approach and yet lends itself to making chemistry lessons more concrete and less ambiguous as improvised materials can easily be used as the case may be.

Recommendations

The obvious results shown by this study will require chemistry educators/teacher worldwide to practice the teaching approach. However, researchers are encouraged to use the approach on wider samples for any possible variations or agreements in findings.

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